REMARKS

The following comments address all stated grounds for rejection, and we believe place the presently pending claims, as identified below, in condition for allowance. Upon entry of this paper, claims 8, 13, 14 and 26 have been amended, no claims have been canceled, and no claims have been added as new claims, thus claims 1-26 are presently pending in this Application. No new matter has been added.

Objections

Objection to Drawings

The Draftsperson objected to the informal drawings submitted with the Application. Formal drawings have been prepared and are submitted herewith. The objection to the reference number 60 appearing in Figure 5 has been addressed by preparing and submitting herewith a substitute page 6 of the specification referencing the number 60 in Figure 5.

Objection To Specification

The examiner requested detailed information about Pro/Engineer 2000i indicating that it appeared to be reasonably necessary to the examination of the Application. Although Applicant disagrees that the information is necessary to the examination (for the reasons stated below), Applicants have submitted a white paper from Parametric Technology Corporation on the Pro/ENGINEER 2000i entitled *"Adding Flexibility to the Design Process"*, dated August 1999, which discusses the product in detail.

Rejections

Rejection of claims 1-22 based on §112, First Paragraph (Lack of Enablement)

The Examiner rejects claims 1-22 as containing subject matter that was not described in the specification in such a way as to enable one skilled in the art to which it pertains, or with which it is most nearly connected, to make and/or use the invention. The Examiner states that Applicant has referred to the CAD package as the Pro/Engineer 2000i from Parametric Technology Corporation of Waltham, Massachusetts but failed to disclose relevant and necessary details in the specification. However the reference to Pro/Engineer 2000i is not an attempt to incorporate the details of the software Application by reference, but rather an attempt to note the software Application as a typical CAD/CAM package to which the present invention applies. The Examiner's attention is directed to page 3, lines 16-22 in the Application that immediately precedes the reference to Pro/ENGINEER 2000i. Applicant states "Those skilled in the art will appreciate that the present invention is not limited to implementations where a CAD package is used, but more generally, the present invention may also employ other types of programs that model objects with models that contain geometric and/or numerical data. Hence, the present invention may be practiced with computer-aided manufacturing (CAM) programs, CAD/CAM packages, industrial design programs and graphical modeling programs, for example." Clearly, not only has Applicant not restricted the present invention to a particular CAD package, the Pro/ENGINEER 2000i CAD package, but Applicant has also indicated that other types of programs that model objects, in addition to CAD packages, are within the scope of the present invention.

The reference to Pro/ENGINEER 2000i that appears in the Application is made to illustrate the discussion that follows by noting Pro/ENGINEER 2000i as an example of a program performing parametric modeling, but a detailed understanding of Pro/ENGINEER 2000i is not required to enable those skilled in the art to understand the invention described in the Application. The principles of object modeling are well developed, and the focus of the Application is on the novel aspects of the invention rather than upon the underlying technology well understood by

practitioners in the field. The features of the invention that are novel claimed elements are sufficiently described when considered in combination with the knowledge of the skilled practitioner.

Rejection of claims 13, 14 and 26 based on 35 U.S.C. §112, Second Paragraph (Claims Indefinite)

The Examiner indicated that claims 13, 14 and 26 were rejected for being indefinite for failing to point out what was claimed. Claims 13 and 14 were rejected for failing to indicate which integrating step in base claim 8 was being referenced. Claim 26 was rejected for improperly claiming dependency. Claims 13, 14 and 26 have been amended and are now believed to be in condition for allowance.

Rejection of claims 1-2, 5-8, 11-14, 19-20 and 23-26 pursuant to 35 U.S.C. §102(a)

The Examiner rejected claims 1-2, 5-8, 11-14, 19-20 and 23-26 pursuant to 35 U.S.C. 102(a) as being anticipated by Fane, *"Your Table is Waiting..."*, CADalyst, January 1999, pages 70-75. The Applicants respectfully traverse each of these rejections for the reasons stated below.

The Examiner indicated that elements of claim 1 were disclosed by Fane. Fane describes a computer system running a CAD package that is used in conjunction with a Microsoft Excel spreadsheet. The article describes a methodology to tie a set of parameters to the Excel spreadsheet. The Excel spreadsheet acts as a database from which the CAD model is fed parameter values. The data is communicated in one direction only, from the spreadsheet to the CAD model. The CAD model does not feed values to the Excel spreadsheet after the association between the two files has been established.

Claim 1 of the Application describes a computer system running a CAD package and an external Application program (EAP). The CAD package includes a model of an object. The model of the object includes output data from the EAP. The model is modified and a determination is reached that the modification requires recalculation of the EAP output data. New input data is sent to the EAP in response

to the determination that the modification of the model requires recalculation of the EAP output data. New output data is received back from the EAP. In other words, a two way communication process by which the CAD package automatically determines the need to send new input data to the EAP, run it, and obtain new output data from the EAP, is disclosed. As noted previously, Fane discloses only a one way communication process for the data.

The Examiner indicated that claim 2 was also disclosed by Fane. Claim 2 includes the step of calling the EAP from the CAD package. Fane however does not reveal a two way data communication process by which changes in the object model are reflected in the EAP. The cited section describes a situation where the Excel spreadsheet acts as a database and supplies values for variables in the object model.

Claim 5 is dependent on claim 1 and includes the step of the EAP performing an analysis on at least a portion of the model to produce the original output data and the new output data. Claim 6 indicates that the analysis of claim 5 is an engineering analysis. Fane, particularly the cited portion at page 75 column 2 paragraph 1, describes the process of association between the data in the Excel spreadsheet and the design variables within AutoCAD, and how AutoCAD behaves during this association. Fane indicates that cells can contain relations and references to other cells. The Excel data is fed as input to the AutoCAD application, AutoCAD does not feed any information to Excel. Accordingly, the computations in Excel cannot describe an analysis on a portion of the AutoCAD model as required by claims 5 and 6, since Excel is not receiving data from AutoCAD.

Claim 7 is dependent upon claim 1 and indicates that the present invention includes the steps of further modifying the model, determining that the modification requires further calculation of the output data from the EAP and accordingly determining new output data. The Examiner indicated that Fane at page 72, column 3, paragraph 4 through page 74, column 1, paragraph 1 disclosed the same steps. Applicant respectfully disagrees. The cited material is not a step of further modifying the model, determining that the modification requires further calculation of the output data from the EAP and accordingly determining new output data. The cited material describes two sets of functionality for editing a value in Mechanical desktop (the

CAD package). The material describes editing the equation that drives a value inside Mechanical Desktop (which has nothing to do with Excel (the EAP)), and secondly the material describes associating a variable with an external parameter file such as Excel (specifically with a cell value in the spreadsheet). When the spreadsheet does not exist, one is automatically created. This is not the same thing as claim 7 which provides that at any time a model is modified the system automatically determines if the EAP has to be executed, and automatically executes it in order to get new outputs corresponding to the performed modifications. Instead the Excel spreadsheet is performing as a database providing input values for the CAD application. The subsequent data input from the CAD program to the spreadsheet is missing.

Independent claim 8 has been modified to clarify that an object method is contained within the record of the model. The object method includes the steps of exporting data from a CAD model in a CAD program to an external application program (EAP), using the exported data as input data to execute the EAP and obtain output data from the EAP, importing the output data into the CAD program from the EAP and integrating the output data into the CAD model. The method is executed and then the CAD model is modified so that the input data to the EAP changes to new input data. Following the modification, the output data is updated by calling the EAP and passing the new input data to the EAP following the modification of said model. After the EAP has run on the new input data, the updated output data is automatically integrated into the CAD model without a user request. As noted, the step of exporting data from the CAD model to the spreadsheet is missing as are the other elements of claim 8 since the Excel spreadsheet only functions as a database which sends data in one direction only.

Claims 11 and 12 are dependent upon claim 8 and include the two-way data communication process discussed above. As noted above, Fane fails to disclose the limitations of the base claim 8.

Claims 13 and 14 have been amended to clarify that the integrating step includes adding output data from the EAP into the CAD model or automatically integrating updated output data from the EAP into the CAD model. The Fane reference does not disclose the automatic integration of updated data into the CAD

model as it doesn't disclose receiving updated input data from the CAD model. As noted, Fane also lacks the elements of the base claim 8. Also, regarding claim 14, there is no mention in Fane of adding geometric entities to the CAD model. Fane only discusses adding parameters to the model.

The Examiner indicated that claim 19 was anticipated by Fane. The Applicant respectfully disagrees. Fane describes the Mechanical Desktop User interface for modifying a parameter. The procedure described is not part of a method involving an External Application Program. Rather, the described procedure is for a workflow the user must follow in order to associate a Mechanical Desktop model to an Excel spreadsheet that does not exist and has to be created. In contrast, claim 19 refers to a CAD model that is already associated with an EAP. Additionally, claim 19 indicates that the step of determining that the modifying of the model requires recalculation of the output data from the EAP is performed automatically by the computer system and not by the user. Claim 19 includes the same element of changing the EAP (spreadsheet) to reflect the changes in the model as discussed above. As noted Fane does not include updating the EAP to reflect changes in the model. Claim 20 is dependent upon claim 19 and the missing elements of claim 19 are therefore missing from claim 20.

Claim 23 is dependent upon claim 19 and was also rejected by the Examiner as being anticipated by Fane. Claim 23 indicates that the EAP performs analysis on at least a portion of the model to produce the output data and the new output data. In support of the rejection, the Examiner cites language in Fane referring to cells in the spreadsheet containing formulas and references to other cells within the spreadsheet. The analysis required by claim 23 is more than the application of a formula as disclosed in Fane. The elements of claim 19 which are included in claim 23 are also missing as discussed previously.

Claims 24-26 claim a method of importing data into a CAD program from an EAP, integrating the output data into a CAD model of an object, modifying the model so as to require the updating of the output data, and automatically updating the output data by calling the EAP with new input data without a user request. As previously discussed, the method disclosed in Fane is a one way data communication process

with the EAP supplying input for the model but not vice-versa as required by claims 24-26.

Rejection of claims 3-4, 9-10, 15-18 and 21-22 pursuant to 35 U.S.C. §103

The Examiner indicated that claims 3-4, 9-10, 15-18 and 21-22 were rejected pursuant to 35 U.S.C. §103 as being obvious based on Fane in view of Cottrell et al, "CHDStd- A Model for Deep Submicron Design Tools", Design Automation Conference 1998, Proceedings of the ASP-DAC 1998, Asia and South Pacific, pages 249-255 (hereafter "Cottrell et al"). For the reasons discussed below, the rejections are respectfully traversed.

Cottrell et al discuss an Integrated Data Model (IDM) technology being used in semiconductor chip design. The IDM works with a central repository of chip component data that is used during chip design. The IDM supports a callback feature that allows an application to register methods to be invoked on specific object events.

All of the claims rejected pursuant to 35 U.S.C. §103 focus on the registration of the EAP with the CAD package. For example, claim 3 is dependent on claim 1 and includes the additional element of registering the EAP with the CAD package. Claim 4 is dependent on claim 3 and indicates that the registering step registers a callback to the EAP from the CAD package. Claim 21 is dependent upon independent medium claim 19 and is otherwise the same as claim 3. Claim 22 is dependent upon claim 21 and is otherwise the same as claim 4. Claim 9 is dependent upon independent claim 8 and indicates the step of registering the EAP with a CAD program. Claim 10 is dependent upon claim 9 and indicates that the registering step registers a callback that is called from the CAD program to access the EAP. For all of the claims rejected pursuant to 35 U.S.C. §103, the Examiner indicated that it would have obvious for one of ordinary skill in the art to combine the invention of Cottrell et al with the teachings of Fane to arrive at the claimed invention. However, the teachings of Fane do not include all of the elements of the underlying independent claims. Assuming for the sake of discussion that there was some motivation to combine Cottrell et al with the teachings of Fane, the combination would still lack all of the elements of the claimed invention.

Similarly, independent claim 15 is for a CAD system and includes a registration facility for registering the EAP with the CAD program so that the CAD program calls the EAP when the output data from the EAP in the model needs updating as a result of changes to the model. The system of claim 15 also includes a CAD program, an EAP external to the CAD program, and a model of an object that contains output data from the EAP. Claim 16 is dependent upon claim 15 and includes the additional element of registering the EAP with the CAD package. Claim 17 is dependent upon claim 15 and indicates the model is a feature-based model. Claim 18 is dependent upon claim 15 and indicates the model is a parametric model. Neither Fane or Cottrell et al teach or disclose the step of calling the EAP to update the output data as a result of changes in the model. In addition, since elements of the base independent claim are missing, the combination of Fane and Cottrell et al also does not teach or disclose the claimed dependent claims 16-18.

CONCLUSION

In view of the foregoing remarks, Applicants contend that claims 1-26 presently pending in the Application are patentable and in condition for allowance. Accordingly, Applicants request the allowance of the Application. We invite the Examiner to call the undersigned at (617) 227-7400 if the Examiner deems there are any remaining issues.

Respectfully submitted,
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Date: January 6, 2003

"VERSION WITH MARKINGS TO SHOW CHANGES MADE"

IN THE CLAIMS

Please amend claim 8, 13, 14 and 26 as follows.

8.(Amended) In a computer system having a computer-aided design (CAD) package for manipulating a model of an object, a method, comprising the steps of:

executing an object method recorded in said model of an object, the recorded object method comprising the steps of:

exporting data from a CAD model in a CAD program to an external application program (EAP);

using the exported data as input data to execute the EAP and obtain output data from the EAP;

importing the output data into the CAD program from the EAP;

integrating the output data into the CAD model;

modifying the CAD model so that the input data to the EAP changes to new input data;

updating the output data by calling the EAP and passing the new input data to the EAP following the modification of said model; and

automatically integrating the updated output data into the CAD model without a user request.

13. (Amended) The method of claim 8 wherein ~~the~~ at least one of said integrating the output data into the CAD model and said automatically integrating the updated output data into the CAD model comprises adding parameters to the CAD model.

14. (Amended) The method of claim 8 wherein ~~the~~ at least one of said integrating the output data into the CAD model and said automatically integrating the updated output data into the CAD model comprises adding geometric entities to the CAD model.

26. (Amended)The computer-readable medium of claim 24 ~~28~~ wherein the model is parametric.

discussion below, it is presumed that the CAD package 10 and EAP 14 reside on a single computer system 50.

Figure 5 is a block diagram illustrating a suitable configuration for the computer system 50. The computer system 50 includes a central processing unit (CPU) that executes computer instructions. The computer system 50 includes a CPU 60, video display 62, keyboard 64, a mouse 66 and an audio output device 68. Those skilled in the art will appreciate that the computer system configuration shown in Figure 5 is intended to be merely illustrative and not limiting of the present invention. The computer system 50 may include different peripheral devices from those shown in Figure 5. Moreover, the computer system 50 may be implemented as a tightly coupled multiprocessor system or even as a distributed system. The computer system 50 may be implemented as a network computer, a personal computer, a mini-computer, a mainframe computer, a super computer, or any of a number of other different types of computer systems.

The computer system 50 includes a network adapter 70 for interfacing with the network 82. The computer system 50 also includes a modem 72 for communicating with remote computing resources over telephone lines, cable lines or wireless communication pathways. The computer system 50 includes a storage 74 that may include both primary memory and secondary memory. The storage 74 may include computer-readable media and removable media such as optical disks, magnetic disks and the like. The storage 74 holds one or more application programs 76. These application programs 76 include the EAP 14. The storage 74 may also hold one or more representations of models 78 for geometric objects. Lastly, the storage 74 may hold a copy of the CAD package 10.

The CAD package 10 represents geometric objects using models that are hierarchical in nature. A model may be an assembly that is comprised of multiple parts. Figure 6 shows an example of an assembly 90 that is composed of parts 92, 94 and 96. Suppose, for example, a designer wishes to generate a model that represents an automobile engine. This automobile engine is an assembly that is comprised of many parts, for example, a four-cylinder engine may include four separate cylinder parts.

Each part within a model contains a number of different types of information. Figure 7 depicts the information that is maintained for a part database 98. The part database includes features 100 as well as a specification of geometry 102. The part

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Review of Parametric Technology Corporation Pro/ENGINEER 2000*i*

"Adding Flexibility to the Design Process"

August 1999

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Parametric Technology Corporation
Pro/ENGINEER 2000*i*

"Adding Flexibility to the Design Process"

Abstract

This paper describes the highlights of the CAD/CAM/CAE solutions provided by Parametric Technology Corporation in the recently released Pro/ENGINEER 2000*i* version of Pro/ENGINEER. In addition to other new features and functions, the Behavioral Modeler for objective-driven design is described. This release represents a major advancement in ease of use and should help users be more creative, innovative, and productive.

PTC positions Pro/ENGINEER 2000*i* as the next generation of its flagship CAD/CAM/CAE solution. It includes a number of new and important capabilities that are described below. Pro/ENGINEER 2000*i* represents a significant investment by PTC that has led to many new enhancements in their already strong product line. The strategy PTC has taken with Pro/ENGINEER 2000*i* is to enhance the products suite's usability while adding capabilities that allow product developers to work more creatively in a number of areas.

The major enhancements to the product include the visually obvious redesign of the user interface to be Windows compliant and simpler; in fact it is now "Designed for Microsoft® Windows" certified. However, the real meat of the release is the set of functional additions to the product line that should improve user productivity. These include Behavioral Modeler for engineering knowledge capture, reuse, and objective-driven design; improved support of large assembly design; an adaptive, feature-based approach to NC; and associative links with other PTC MDA solutions.

Behavioral Modeler

The concept behind behavioral modeling is to allow designers to capture functional behavior and make use of this to drive and adapt their product designs. It streamlines the process of developing an optimal product solution that meets specifications, even in designs with many variables, constraints, and goals. As problems are solved, the solutions are captured in the model, and so they may be reused to improve productivity on future designs. The Pro/ENGINEER 2000*i* implementation of this technology uses the product's inherent capabilities for capturing and modifying parametric models. It extends Pro/ENGINEER's feature-based modeling kernel to incorporate behavioral features in addition to geometric features, so they can be used in creative and novel ways to enhance the design process. This technology is also known as specification-driven, knowledge-based, or goal-driven design. PTC has applied

for a patent for the Pro/ENGINEER Behavioral Modeler.

There are three essential components that are used in Behavioral Modeler:

- Behavioral features capturing information about design specifications such as desired clearances, mass properties, angles of reflection, working envelopes, and other measurements.
- Objective-driven design tools providing visual feedback on product performance against the behavioral feature specifications as changes are made. They automate the discovery of various feasible alternatives or even find an optimal solution.
- Connections to external programs, such as proprietary analysis programs, to behavioral features ensuring that the design model reflects the results produced by these other applications automatically.

Behavioral Features

With Pro/ENGINEER 2000*i*, the engineering specifications are captured in the model as live behavioral features that continually evaluate the performance of the design.

These behavioral features are able to capture very broad design specifications. Examples include standard measurements (such as distances, mass properties, volumes, surface curvature, etc.), user-constructed measurements (such as the angle of reflection of a light path), derived measurements (using equations describing relationships between parameters, e.g., length is twice width), component connections (welds, pin joints, ball joints, slider joints, etc.), and spatial allocation information (external static envelopes called shrinkwraps, and working envelopes).

Behavioral features enable desired performance characteristics to be embedded in the design, extending model intelligence beyond traditional geometry and process intent.

Objective-Driven Design

Objectives can be applied for desired performance values, together with rules that define acceptable ranges for design variables. Pro/ENGINEER 2000*i* automates the process of finding an appropriate solution. It does this by automatically searching the realm of all solutions to produce a set of feasible solutions. This capability can explore a design with multiple, perhaps conflicting objectives (such as cost and performance) and multiple variables. The engineer can investigate these alternative designs that are known to meet the engineering requirements, and select a subset for further refinement or optimization (e.g., minimize material cost while satisfying a container volume goal and adhering to its shape parameters).

In Pro/ENGINEER 2000*i*, the feedback is very visual. To help designers understand the effects of a change, Pro/ENGINEER 2000*i* can display on-screen graphs that show how sensitive design goals are to changes. Users can explore designs by dragging a mechanism through its range of motion and visually detecting potential interferences, or by showing a graph of minimum clearance.

In addition, behavioral features can communicate with other applications, such as a company's proprietary software. This permits an aspect of the product's performance to be evaluated by passing parameters and geometry from Pro/ENGINEER 2000*i* to the external application and then returning the results (for example, modify the dimensions of a duct based on an analysis of fluid flow) back to

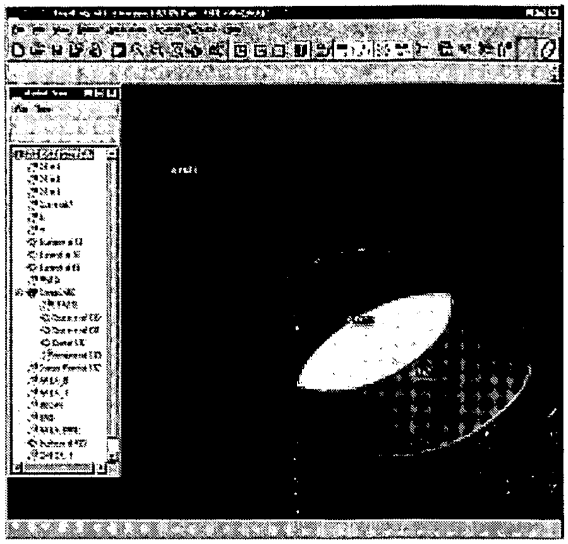

Figure 1—An Air Duct Example

Pro/ENGINEER. Each time an engineer updates the model, the behavioral feature will reference the other application and include its results associatively.

Pro/ENGINEER 2000*i* allows design features to contain both geometric size and shape information as well as performance criteria and captures real design intent within the product's design. This, in turn, provides a source of design knowledge that can be reused and applied throughout a design organization.

An Example

This example investigates the cross-sectional properties of an air duct. In this case, there is no "off the shelf" measurement tool in Pro/ENGINEER to measure the cross-sectional properties of this model. However, the cross-section can be measured in terms of a few standard features. In this example, a point on the duct trajectory at which the surface area is to be measured, a plane (surface) through this point normal to the trajectory, a cut to trim the plane to its intersection with the duct, and a behavioral feature that measures the area of the resulting intersection. This custom measurement is specified as shown in Group XAC in the model tree in the figures. Each of the elements in Group XAC corresponds to part of the measurement process.

- FPNT0—defines a point that floats along the trajectory of the duct
- Surface id 136—defines a planar surface through the point
- Surface id 131—copies the cutting surface (i.e., the internal surface of the duct)
- Cut id 132—Cuts the planar surface with the cutting surface creating a cross-section surface
- Analysis id 133—measures the area of the cross-section surface and graphs the results along the trajectory shown in the charts of Figures 2 and 3

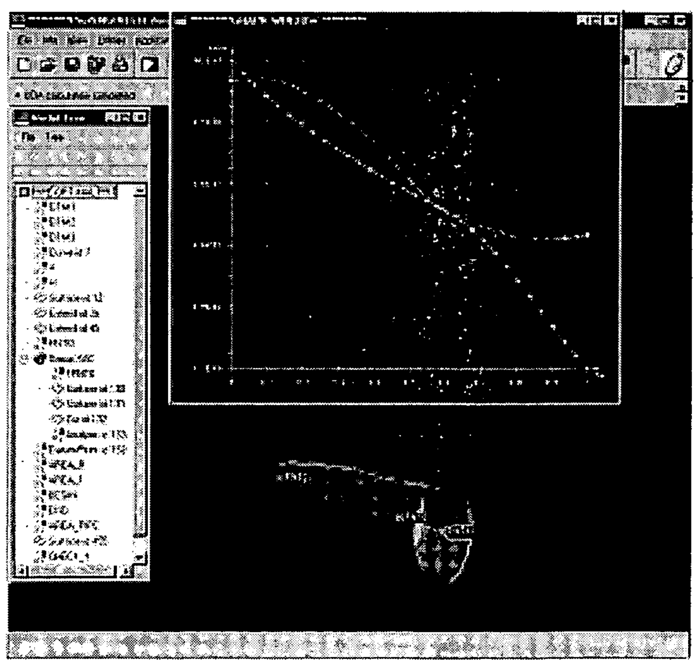

Figure 2—The Goal Cross Section Profile is Dashed

The steps defined in the tree are executed any time the model is re-evaluated. This defined group can be automatically computed for the entire length of the duct or reused on different ducts by other engineers. Note that no programming skills are needed to build and compute this "custom" measurement, it's simply a case of using standard features to construct the measurement. Other engineers can leverage this engineering knowledge by selecting a new duct and its trajectory to measure along.

The figures display the cross-sectional area profile in a graph as well as representing the area magnitude measured at each point with vectors along the duct. This provides the designer with both quantitative and visual design insights.

Taking this example a step further, the user can actually drive the design to a predetermined cross-sectional profile — perhaps the result of historical data or of an analysis in a third-party application. In the case of the example duct, the difference between the required cross-sectional profile (dashed curve in Figure 2) and the cross-sectional profile measured through the custom measurement described above (solid curve) can be captured through a behavioral feature labeled CHECK_1 (at the bottom of the Feature Tree). An optimization study can now be performed to automatically yield the required design, by choosing a goal of minimizing this difference by varying duct shape dimensions within their allowable ranges. The initial design is shown in Figure 2 and the optimized design in Figure 3.

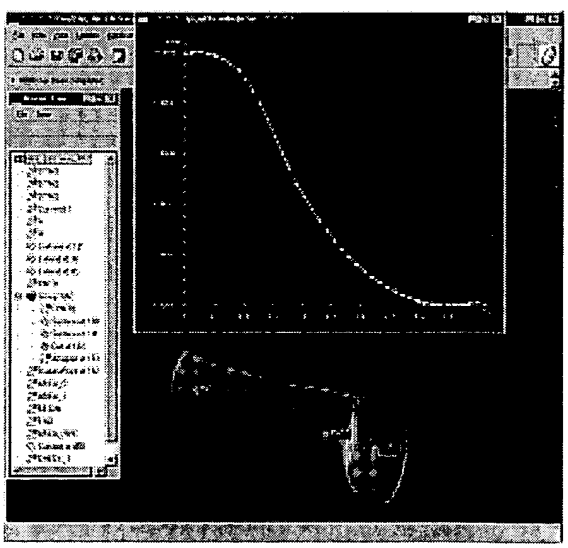

Figure 3—The Result of the Optimization

Behavioral modeling helps designers achieve more refined designs while reducing or eliminating the design – evaluate – redesign – reevaluate cycle that is generally required to optimize a design. Typically, designers have to use a time consuming trial-and-error process to attempt design optimization—which may not result in a truly optimal result. When applied properly, behavioral modeling can achieve a much more refined optimization based on more parameters, testing more possible solutions, much more quickly than designers can be expected to accomplish via traditional parametric modelers. This frees designers from repetitive work and allows them to concentrate on more challenging and innovative concepts.

Assembly Support

Large assemblies present special problems for designers in terms of speed, data accessibility, and evaluation for correctness. Pro/ENGINEER 2000*i* has added functionality to help—notably, shrinkwrap and assembly animation.

Shrinkwrap (a patent-pending technology) is a technique that allows users to create a simplified version of a part or assembly that retain accurate representations of its external and mating surfaces while removing all of the internal details. This is like encasing an object in shrinkwrap plastic. This results in a much

smaller sized model that can be used within Pro/ENGINEER assemblies and design processes without compromising accuracy.

Since the shrinkwrap model does not include internal details, it can be used to provide interface geometry to outside organizations without compromising sensitive product design information. Entire assemblies can be shrinkwrapped, hiding the complexity of their assembly structure and allowing the assembly to be used as a single part model in the on-going design process.

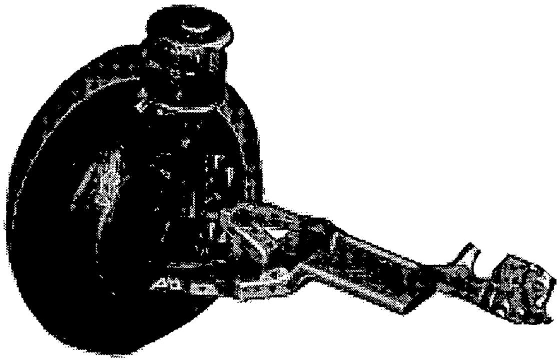

Figure 4—Shrinkwrap of Moving Assembly

The mass properties of shrinkwrapped assemblies and parts are embedded within the object, so they can be used throughout the design and analysis process.

Options during shrinkwrap creation include suppressing holes (further reducing the size of the model, but also removing outer detail), and shrinkwrapping a moving assembly. When a moving assembly is shrinkwrapped, the result is a skin that represents the envelope of the motion's extents. This is effective for determining clearances around moving parts and creating space reservation volumes.

Interactive mechanism animation within the design environment helps designers quickly understand the basic functioning of their design, without having to add a lot of detailed joint constraints and physical rules such as are needed in traditional mechanisms packages. This allows designers to start evaluating the validity of their designs early in the design process, avoiding unnecessary development of detail for unworkable designs.

These animations can be driven by user interaction (dragging on a part of an assembly) or by motion drivers and joint constraints. Joint conditions and constraints can be continuously evaluated to prevent inconsistent configurations of parts in assemblies.

By integrating shrinkwrap with mechanism analysis, Pro/ENGINEER 2000*i* allows users to create swept solid volumes of motion envelopes. These motion envelopes are accurate solid models that represent that exact space through which an assembly moves. Envelopes are single solid objects that can be used in other design activities. This allows users to share lightweight motion envelopes with each other, so that they can design around an accurate representation of the space that the assembly will require during motion–designing a fender around a suspension is an example.

PTC uses the same approach for defining joint and constraint conditions across its CAD/CAE products, so that constraints, joints, and drivers can be defined either in Pro/ENGINEER or Pro/MECHANICA and re-used in either application.

Associative Topology Bus

PTC's Associative Topology Bus (ATB) provides a very high degree of interoperability among the company's MDA products. The ATB provides not only data sharing among Pro/ENGINEER 2000*i*, Pro/DESKTOP™ 2000*i*, CDRS 2000*i*, ICEM Surf 2000*i*, and CADDS® 5*i*. The ATB maintains associative links when designs are

moved from one CAD product to another. For instance, a user can design a part in Pro/DESKTOP and move it into a Pro/ENGINEER assembly to create a drawing and toolpath. Then they can modify the original part in Pro/DESKTOP and the NC toolpath and the drawing in Pro/ENGINEER will be updated associatively and automatically to reflect the changes made in Pro/DESKTOP.

The ATB overcomes a criticism of previous PTC efforts at presenting a desktop through high-end CAD strategy—namely an inability to share data among the various levels of PTC's CAD products. The ATB provides a very advanced level of integration that extends well beyond data sharing. ATB technology is nearing complete bi-directional associativity among PTC i-Series products and PTC has indicated that it may soon be extended to work with selected third-party CAD systems.

Pro/MECHANICA 2000*i*

For mechanical assembly analysis, PTC provides an integrated module called Pro/MECHANICA 2000*i*. This module is built to be used by designers and engineers as opposed to analysis experts. To support this, Pro/MECHANICA provides a number of different analyses, all executed from a common model setup preparation.

Pro/MECHANICA allows users to execute kinematic mechanism analysis, deformation of structures, vibration, and thermal analysis. To streamline the process for engineers, the product automatically meshes Pro/ENGINEER, CADDS 5*i*, and Pro/DESKTOP parts to be analyzed. Meshing, loads, and constraints all associatively update when the geometric models to which they are applied change. Loads and constraints are applied directly to the part geometry, not to the mesh. Meshes can be prepared for third-party solvers as well as Pro/MECHANICA.

Assembly analysis animation includes kinematically-driven and free motion in which the user can drag a part to a new position while the rest of the assembly follows. The mechanism analysis automatically uses Pro/ENGINEER joint conditions such as alignments and mating, to control motion. Motion analysis can include cams and contact simulations (such as backlash in a gear system). Collision detection during the animation can highlight or stop the motion. Pro/ANIMATE can use animation and joint constraint information as well.

Deformation includes non-linear, large displacement analysis for situations such as snap-fit of plastic parts.

Pro/MECHANICA shares optimization technology with Behavioral Modeler and can be used to provide advanced structural, thermal, vibration, and motion studies as part of a customer's behavioral modeling solution. For sensitivity studies, it automatically builds charts to show the behavior of parameters.

Pro/MECHANICA 2000*i* has a new Windows-style user interface that is compatible with the other i-Series modules. This interface is used for the integrated mode with Pro/ENGINEER and for the standalone product. The user interface retains some of the old style menus. These are being removed with each new release and are expected to disappear altogether in the near future.

The standalone product is able to work with models from not only PTC's CAD products but also CATIA and Unigraphics, and imported data in DXF and IGES formats. It now contains the same modeler kernel as Pro/ENGINEER.

Expert Machinist

Expert Machinist is PTC's new approach to NC. It is feature-based and adaptive. It allows manufacturing engineers to define machining operations for various types of manufactured features such as holes and pockets. Expert Machinist includes a number of pre-defined manufacturing features including various types of holes, pockets, faces, etc. Manufacturing features can contain both a geometric definition and a manufacturing method. For instance, a pocket feature can contain a pre-defined NC toolpath that is a company's standard method for machining that type of pocket. This is a very powerful concept that can save time and help enforce standard manufacturing practices. The machining strategy for each feature is combined into the total NC program for the part.

The feature recognition technique used in Expert Machinist allows users to re-feature a design model with manufacturing features, overlaying the design features. To do this, a manufacturing engineer selects geometric regions on the design model such as a pocket and declares it to be a pocket feature. The user is able to assign the type of hole or pocket that is being defined. This does not change the geometry of the part's model in any way. It also does not destroy the designer's features, even though design features and manufacturing features are generally not equivalent to each other (e.g., a designer may design a strengthening rib while the manufacturing engineer needs to machine a pocket on each side of the rib). Unfortunately, Expert Machinist can't automatically recognize and assign the proper type of manufacturing feature—we don't know of any software that can reliably do this for the broad range of part shapes that can be defined in a system such as Pro/ENGINEER.

The defined manufacturing features remain associative with the design and its design features so that changes to the design propagate through the manufacturing instructions.

This technology should allow manufacturing engineers to produce machining instructions more efficiently and with less effort. The encapsulation of machining instructions with features also provides standardization of

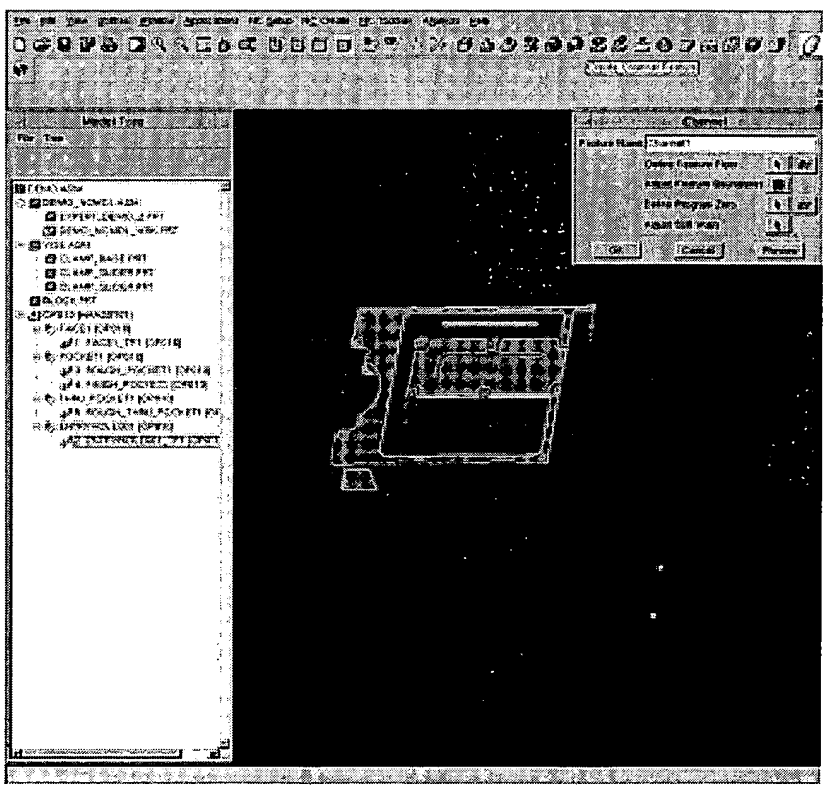

Figure 5—Expert Machinist

manufacturing processes.

Today, Expert Machinist handles 2 1/2-axis production machining of prismatic parts. Machining for other types of parts is planned for future releases.

Import Data Doctor

A new utility helps users repair problems with geometry imported into Pro/ENGINEER 2000*i* from other CAD, CAM, and surface design products. This function provides both automatic and user-directed fixes for common problems with translated geometric models. It can repair overlaps and gaps between surface patches and can heal "leaky" solids whose edges don't match. Imported surfaces can be repaired and refined in a number of ways. The Import Data Doctor helps streamline the data importing process and helps assure that imported models can be used in Pro/ENGINEER 2000*i*, for example in machining operations.

User Interface

Over the past several years, PTC has been redefining all of their product line's user interface to become more Windows-compliant. With Pro/ENGINEER 2000*i*, a major update has been achieved. The previous cascading menus are being replaced with menus, icon palettes, and dialog boxes. While the changeover is not yet complete, it is progressing quite well. The initial changes are concentrated in the most broadly used areas of the system—such as product design creation.

The important factors of the new user interface include familiarity, streamlining, fewer commands, and ease of use. Familiarity because the interface is similar to that of MS Office and other MS Windows applications, which are used frequently and thus, are easily recognized by many users. Streamlined in that many commands require fewer user interactions to complete. Fewer commands due to the combination of many commands into lists of options and input parameters in dialog boxes. All of these contribute to a user interface that is easier to learn, remember, and re-learn (especially for casual users). In addition to these, functions are easier to find and dialog boxes allow users to set frequently used options and not have to re-establish them each time a command is activated. Inappropriate commands are de-activated and grayed-out so users know immediately which commands are valid actions for selected data. Pop-up help provides a short description of each command as the cursor is paused over it. Commands are grouped within user action categories in the menu system.

Icons can be used in addition to menus. Users can customize the default icon palettes, in

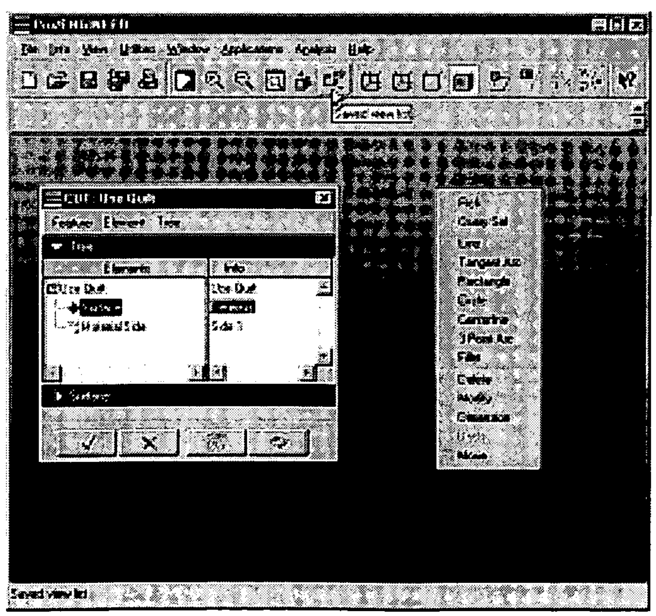

Figure 6—Windows User Interface

much the same way as they can be in MS Office. New icons can be assigned to commands and user-developed macros. Right clicking on an object pops-up a menu of actions appropriate for that object in the current context.

For power users there are pre-defined keyboard shortcuts for many commands. These can be used to by-pass the menus and provide very rapid access to many functions. Users can add shortcuts for commands and macros. Pro/ENGINEER is now "Designed for Microsoft® Windows" certified by Microsoft. This is especially important as PTC indicates that over 60 percent of new Pro/ENGINEER licenses are delivered on Windows platforms.

Java-Based Customization

A new method of customizing Pro/ENGINEER 2000*i* has been developed. Called J-Link, it allows people to create functions using the Java language that can be executed inside Pro/ENGINEER 2000*i*. J-Link can be used with Pro/ENGINEER's other programming tools including Pro/PROGRAM (macro language), Pro/TOOLKIT (C language API), and Pro/WEB.LINK (JavaScript API). J-Link is included in the baseline Pro/ENGINEER Foundation package

An important advantage of J-Link over other customization methods is that J-Link produces platform independent customizations that can be used with the native Windows and Unix versions of the product, avoiding duplicate effort for companies that use Pro/ENGINEER 2000*i* on both platforms.

Summary

While PTC has recently placed a major emphasis on PDM and other technologies, Pro/ENGINEER 2000*i* furthers their commitment to the mechanical CAD market. Pro/ENGINEER 2000*i* is the result of a substantial investment by the company in their flagship product. It contains major new functionality and enhancements of existing products, with more to come.

PTC has also demonstrated that their architecture remains extensible to support new technological innovations such as behavioral modeling and shrinkwrap.

Behavioral Modeling is a very good entry into an area of design that has huge potential to improve how rapidly and effectively correct designs can be generated. The Pro/ENGINEER 2000*i* implementation appears to be robust and extensible. It allows design solutions to be evaluated and optimized, assuring more correct designs.

The Associative Topology Bus has the potential to provide associativity and design interoperability among all of PTC's diverse CAD/CAM products.

The user interface is much more intuitive and cleaner—it should make Pro/ENGINEER 2000*i* more accessible, providing the opportunity for more casual users to take advantage of Pro/ENGINEER. When this user interface is rationalized across the complete product line it will reach its full potential. This is a major undertaking and will take some time to accomplish, although the process is well underway.

Pro/ENGINEER 2000*i* delivers significantly enhanced capabilities. At under $6,000, it is very attractive both for new 3D users and those moving from lower-end, limited scalability solid modeling and drafting systems.

Pro/ENGINEER 2000*i* makes CAD more of an engineering tool as opposed to a tool to document known designs. All in all, Pro/ENGINEER 2000*i* is a major step forward that provides a substantial number of advantages and improves productivity for current and new Pro/ENGINEER users.